# Life Prediction/Reliability Data of Glass-Ceramic Material Determined for Radome Applications

Brittle materials, ceramics, are candidate materials for a variety of structural applications for a wide range of temperatures. However, the process of slow crack growth, occurring in any loading configuration, limits the service life of structural components. Therefore, it is important to accurately determine the slow crack growth parameters required for component life prediction using an appropriate test methodology. This test methodology also should be useful in determining the influence of component processing and composition variables on the slow crack growth behavior of newly developed or existing materials, thereby allowing the component processing and composition to be tailored and optimized to specific needs.

Through the American Society for Testing and Materials (ASTM), the authors recently developed two test methods to determine the life prediction parameters of ceramics. The two test standards, ASTM 1368 for room temperature and ASTM C 1465 for elevated temperatures, were published in the 2001 Annual Book of ASTM Standards, Vol. 15.01. Briefly, the test method employs constant stress-rate (or dynamic fatigue) testing to determine flexural strengths as a function of the applied stress rate. The merit of this test method lies in its simplicity: strengths are measured in a routine manner in flexure at four or more applied stress rates with an appropriate number of test specimens at each applied stress rate. The slow crack growth parameters necessary for life prediction are then determined from a simple relationship between the strength and the applied stress rate.

Extensive life prediction testing was conducted at the NASA Glenn Research Center using the developed ASTM C 1368 test method to determine the life prediction parameters of a glass-ceramic material that the Navy will use for radome applications. This project was done in cooperation with Science & Applied Technology (based in California). A wide range of applied stress rates ranging from 70 MPa/sec to $7 \times 10^{-4}$ MPa/sec (six stress rates) was used, with 30 test specimens at each stress rate, totaling about 200 test specimens for the whole test matrix. The test results are shown in the graph. Peculiar to this material is that the scatter of strength was considerably small, with a resulting Weibull modulus (a measure of strength scatter) of about 45 in contrast to about 15 for typical ground ceramics. Hence, the test material was regarded as an ideal material to verify the test methodology as well as its underlying fundamentals. It can be seen from the graph that the data fit to the theory (solid line) is excellent with a correlation coefficient of 0.990, thus confirming the applicability of the test method. From the results in the graph, the corresponding life prediction parameters of the material were determined to be $n = 21$ and $D = 187$, with the units of strength in megapascals and stress rate in megapascals per second. Other material properties--such as tensile strength, fracture toughness, hardness and elastic modulus--were also evaluated. The determined life prediction parameters together with appropriate properties were further used to predict the actual component life

and reliability analyses using the CARES/*Life* design software developed by Glenn. In addition, the authors recently developed a life-prediction methodology using the exponential slow crack velocity formulation to relate its lifetime prediction parameters to those in the power-law formulation.
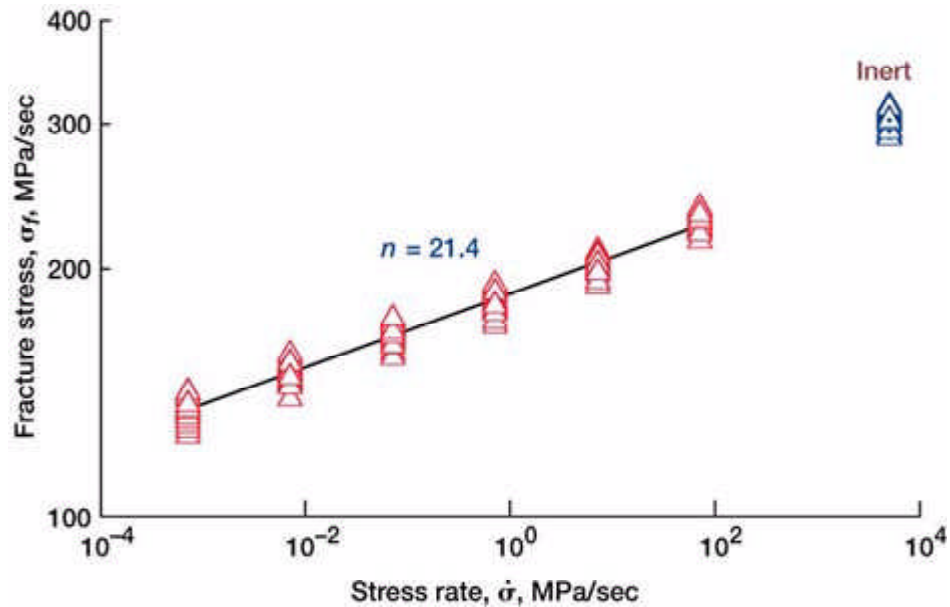


*Fracture strength as a function of stress rate determined for glass-ceramic in room-temperature distilled water, in accordance with ASTM C 1368. Inert strength was determined in oil. A total of 30 test specimens were tested at each stress rate.*

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